

Wettability was determined in two cases: a lead immediately after plating and a lead exposed to 150° for 168 hours after plating. Measurements were made ten times for each test condition to obtain an average value.

The wetting time and wetting force for each composition are shown in Fig. 5 and Fig. 6, respectively. It became apparent from the result of wetting time shown in Fig. 5 that the higher the Bi content, the better wettability in the Sn-Bi alloy plated leads tested immediately after plating, while wettability is deteriorated at below 1 wt% Bi and at 23 wt% Bi when the leads are exposed to a high temperature of 150° for 168 hours. It can be said that at Bi contents of below 1 wt%, wettability was low because the wetting time became long while the wetting force was ensured as shown in Fig. 6. Therefore, it became apparent that a desirable Bi content is from 1 to 20 wt% in order to obtain sufficient wettability even with the Sn-Bi alloy layer.

Stress generated in the interface is high when materials with a great difference in thermal expansion coefficient are bonded together, when materials are used in an environment of great temperature difference, and the like. The bonding strength in the interface must be approximately 10 kgf or more in order to ensure sufficient reliability. Therefore, it became evident from Fig. 4 that fillet

strength of 10 kgf or more cannot be obtained by directly providing an Sn-Bi layer onto the Fe-Ni alloy (42 alloy). It is believed that this is because the compounds at the interface are not sufficiently formed.

- 5 Therefore, a Cu plating layer of about 7  $\mu\text{m}$  on average was applied to the Fe-Ni alloy (42 alloy) and an Sn-Bi alloy plating layer was applied to this Cu layer in order to raise the reactivity with the solder in the interface and bonding strength was measured. The
- 10 fillet strength, in the case of no Cu layer, is also shown in Fig. 7. Bonding strength of not less than 10 kgf was obtained with the exception of the case of 23 wt% Bi and the effect of the underlayer of Cu was capable of being verified. By adopting this electrode
- 15 structure it was possible to obtain a bonding strength of about 12.1 kgf or more that is obtained immediately after soldering of a lead made of the 42 alloy on which an Sn-10Pb alloy layer is formed, which is soldered by means of a eutectic Sn-Pb alloy solder, and whose
- 20 bonding strength is also shown as a comparative solder in Fig. 7. Furthermore, as shown in Fig. 8, flat portion strength was also capable of being improved by forming a Cu layer under the Sn-Bi alloy layer. The Cu layer may be applied to the 42 alloy as described above
- 25 when a lead frame of 42 alloy is used. However, when a Cu lead frame is used, this lead frame may be allowed to serve as the Cu layer or a further Cu layer may be formed in order to eliminate the effect of other

elements which may sometimes be added to the lead frame material to improve rigidity. The wettability of the example leads to which this Cu layer is applied is also shown in Figs. 5 and 6. There is scarcely any effect of the Cu layer and sufficient wettability was capable of being obtained at 1-20 wt% Bi, although wettability also deteriorated at Bi contents of not more than 1 wt% when the lead frames were exposed to a high temperature. Incidentally, an Sn-2.8Ag-15Bi was used in the examples shown in Figs. 7 and 8. However, the formation of an underlayer of Cu is effective in improving bonding strength even in systems of low Bi content, for example, an Sn-2Ag-7.5Bi-0.5Cu alloy.

The method of application of the above Sn-Bi alloy and Cu layers is not limited to plating and these layers can also be formed by dipping, deposition by evaporation, roller coating or metal powder application.

Thus, in order to investigate the reason why various types of the electrode materials have different strengths from one another, cross-sectional surfaces of bonding portions were observed after polishing. Further the fractured surfaces of samples subjected to the pull test were observed under an SEM. The results obtained in the typical combinations are described below.

First, Fig. 9 shows an observation result in the case where a lead obtained by applying an Sn-10Pb